HOG CHOLERA TRANSMISSION THROUGH INFECTED PORK

A THESIS

PRESENTED TO THE FACULTY OF THE GRADUATE SCHOOL OF CORNELL UNIVERSITY FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

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pp. 303 - 330

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HOG CHOLERA TRANSMISSION THROUGH INFECTED PORK*

R. R. BIRCH, Ithaca, N. Y.

There is no other acute infectious disease of animals which is so widespread as hog cholera. It occurs in almost, if not quite, all countries in which swine are raised, and in some countries there are few large areas entirely free from it. While it is most prevalent near the more important shipping routes and in localities where large numbers of hogs are raised, it nevertheless appears frequently on remote farms and in localities far removed from busy traffic routes and centers. Its appearance in these seemingly well isolated places has been puzzling, for it is well known that it is caused by a specific virus, and that whenever it appears in a herd, the virus has in some manner been transferred to the herd from other infected animals.

Hog cholera virus, while it is not known to multiply outside the bodies of swine, is very tenacious and resists most natural destructive influences for long periods of time. A very small quantity[1] of it will infect an animal, and it is, therefore, commonly supposed that such casual carriers as crows, buzzards, and also various domestic animals not themselves susceptible to hog cholera, are in a large measure responsible for the many seemingly mysterious appearances of the disease. While the facts at hand do not admit doubt concerning the possibility of hog cholera virus transmission by these carriers, there are good reasons to doubt whether they possess the degree of importance usually attributed to them. Circumstances seem to point to some important means of transmission less precarious than is furnished by such carriers.

Hogs that are fed garbage very frequently contract cholera and garbage often contains pork trimmings. Since garbage feeding is habitual both with farmers who feed only their own kitchen refuse and with men who make a business of removing and feeding city garbage, it seems reasonable to suppose that this practice may

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1. King places the minimum fatal dose of hog cholera virus for a 50 lb. pig somewhere between 1/215 and 1/300 c.c. In his experiments the doses were administered intramuscularly.

be responsible for many new herd infections. Further evidence supporting this belief is found in the facts that marketing the seemingly well animals in newly infected herds is a common practice, and that hog cholera virus appears in the blood stream of infected animals quite early in the course of the disease.

In the past, very little importance seems to have been attached to the transmission of hog cholera through infected bits of pork. Dr. James Law[2] mentions pork trimmings as a possible source of infection, but he lays special stress on dangers incident to feeding slaughter house refuse. Hutyra and Marek[3] make no mention of market pork as a possible means of hog cholera transmission, and neither do Friedburger and Fröhner[4]. Dr. M. Dorset[5] in summarizing the various channels of inter-herd spread of the disease makes no mention of infected pork trimmings. So far as we know the first outbreak traced with any degree of accuracy to infected market pork was one in Canada which McGilvray[6] reported in 1912. Even that outbreak seems to have been regarded as an exception for very little has been done looking toward the prevention of this means of hog cholera transmission.

Anti-hog cholera serum has removed one of the greatest obstacles in the way of hog cholera control. Not only does it protect herds in which the disease is just starting and prevent its appearance in other threatened herds, but it prevents, or should prevent, these herds from being shipped to market at times when they are in condition to infect other swine. It thus removes an almost unbearable hardship to swine breeders that otherwise would accompany the enforcement of strict sanitary measures to prevent shipping cholera infected hogs. It has given good reasons to hope for the more complete control or eradication of hog cholera, and in so doing it has centered the efforts of a large number of veterinarians on a more thorough study of the disease itself, and on sanitary measures for its control. Since it cannot be effectively controlled as long as any one common means of transmission remains unknown or unheeded it has seemed desirable to procure exact experimental data on the effects of feeding susceptible pigs bits of pork such as might be found in garbage.

The experiments have been conducted with three kinds of pork; fresh, refrigerated, and cured. Some of the specimens of each kind were taken from carcasses that would have passed inspection, and others were taken from carcasses that would have

been condemned. In all the experiments, before the specimens were removed for feeding, the hams were scalded and scraped as is done in butchering. Except as otherwise stated the material fed consisted of all or a part of the head of a femur together with adjacent parts. With one exception, experiment No. 1 in table No. 2, the hams all came from small shoats weighing less than one hundred pounds each, a fact which might have considerable influence on results obtained from feeding cured pork. Large hams would naturally be expected to harbor virus in their depths with somewhat greater regularity than small ones when both are subjected to killing influences that work from without.

The susceptible pigs to which the pork trimmings were fed were isolated with great care. In the earlier experiments small fly-tight pens were constructed of screen and matched lumber for this purpose. These were located on a hill several hundred feet from hog yards of any kind. When infection occurred in a pen it was immediately burned, and a new one was constructed on fresh soil for further experiments. The pigs fed in later experiments were placed in small individual fire brick pens so constructed that the attendant could not touch the pigs within. Food and water were introduced through a joint of tile. After each experiment the pen used was cleaned out and a wood fire was kindled inside and allowed to burn for several hours. Thus, in all cases heat, rather than disinfectants, was used to destroy the virus. Most of the pigs were isolated a week or more before being fed and in no case did disease appear previous to feeding. In all cases the experimental pigs were selected from a herd of susceptible animals, and, except as noted, disease did not appear in this herd subsequent to the time the animals were removed. These two facts practically exclude the possibility that any of the experimental animals were infected prior to the time at which they were isolated.

In judging the part played by meat inspection in removing cholera infected carcasses from the market, the federal meat inspection regulations have been selected as a standard, because most of the meat inspected in this country is inspected by federal employees or by others who follow the federal regulations quite closely. Following are the paragraphs that govern antemortem and postmortem inspection in their relation to hog cholera:

Regulation 9, section 2, paragraph 2. "All hogs plainly showing on ante-mortem inspection that they are affected with either hog cholera or swine plague shall be marked 'U. S. condemned' and disposed of in accordance with section 8 of this regulation."

Regulation 9, section 2, paragraph 3. "If a hog has a temperature of 106°F. or higher and is of a lot in which there are symptoms of either hog cholera or swine plague, in case of doubt as to the cause of the high temperature, after being marked for identification, it may be held for a reasonable time under the supervision of an inspector, for further observation and taking of temperature. Any hog so held shall be reinspected on the day it is slaughtered. If upon such reinspection, or, when not held for further observation and taking of temperature, then on the original inspection, the hog has a temperature of 106°F. or higher it shall be condemned and disposed of in accordance with section 8 of this regulation."

Regulation 9, section 2, paragraph 6. "All animals which, on ante-mortem inspection, do not plainly show, but are suspected of being affected with, any disease or condition that, under these regulations, may cause condemnation, in whole or in part, on post-mortem inspection, shall be so marked as to retain their identity as suspects until final post-mortem inspection, when the carcasses shall be marked and disposed of as provided elsewhere in these regulations, or until disposed of in accordance with section 7 of this regulation."

Regulation 9, section 4, paragraph 1. "All hogs, even though not themselves marked as suspects, which are of lots one or more of which have been condemned or marked as suspects under section 2 of this regulation for either hog cholera or swine plague, shall, so far as possible be slaughtered separately and apart from all other animals passed on ante-mortem inspection."

Post-mortem inspection.

Regulation 11, section 4, paragraph 1. "The carcasses of all hogs marked as suspects on ante-mortem inspection shall be given careful post-mortem inspection, and if it appears that they are affected with either acute hog cholera or swine plague, they shall be condemned."

Regulation 11, section 4, paragraph 2. "Carcasses of hogs which show acute and characteristic lesions of either hog cholera or swine plague in any organ or tissue, other than the kidneys or lymph glands, shall be condemned. Inasmuch as lesions resembling lesions of hog cholera or swine plague occur in the kidneys and lymph glands of hogs not affected with hog cholera or swine plague, carcasses of hogs in the kidneys or lymph glands of which appear any lesions resembling lesions of hog cholera or swine plague shall be carefully further inspected for corroborative lesions. On such further inspection—

"(a) If the carcass shows such lesions in the kidneys, or in the lymph glands or both, accompanied by characteristic lesions in some other organ or tissue, then all lesions shall be regarded as those of hog cholera or swine plague, and the carcass shall be condemned.

"(b) If the carcass shows in any organ or tissue, other than the kidneys or lymph glands, lesions of either hog cholera or swine plague which are slight and limited in extent, it shall be passed for sterilization in accordance with regulation 15.

"(c) If the carcass shows no indication of either hog cholera or swine plague in any organ or tissue other than the kidneys or lymph glands, it shall be passed for food, unless some other provision of these regulations requires a different disposal."

Most of the virus used in the experiments was the same as was used in our routine work of serum production. It was of an exceedingly virulent strain obtained originally from Dr. W. B. Niles of Ames, Iowa. Pigs inoculated with 2 c.c. of this virus were usually ready to kill for virulent blood in seven days. In the remainder of the experiments the virus used was obtained from Dr. A. D. Fitzgerald, Columbus, Ohio. This also was of a highly virulent strain.

The method of securing carcasses that would pass inspection was to inject small shoats with 2 c.c. each of virulent blood and record temperatures every twenty-four hours subsequent to injections. When a decided elevation was recorded the pig was killed and autopsied; then the ham was removed and scalded and a specimen secured for feeding. In each case the virus was injected into the right ham and the specimen fed was secured from the left ham. Complete data concerning these animals appears in table No. 1. Relative to the interpretation of results it should be stated that, except as noted, all the lesions produced were of the acute form of hog cholera, and all the animals that sickened displayed symptoms similar to those produced by that disease. The term "typical lesions of cholera" as used in all the tables indicates that the animals in reference revealed on autopsy petechiae in the kidneys, and in addition characteristic hemorrhages (petechiae and ecchymoses) in one or more other organs.

The animals that became infected were killed when severe symptoms developed in order that their blood might be used to hyper-immunize hogs in the routine of serum preparation.

TABLE NO. 1.

Showing temperatures, symptoms, and lesions[1] of pigs from which the specimens fed were taken.
(Tables 2, Section b; 3, section b; 4, section b.)

No. of Pig	Date injected	Date killed	Temperature when killed	Symptoms noted	Lesions found	No. of expt in which specimen was fed
106	Jan. 20	Jan. 23	2 106.2°	None	None	Expt. No. 6 Table 2, Sec. b.
107	Feb. 20	Feb. 23	105.4°	None	Mucosa of bladder**	Expt. No. 7 Table 2, Sec. b.
108	Mar. 30	Apr. 2	105.6°	None	Right inguinal lymph gland** Right sublumbar lymph gland** Left sublumbar and cardiac lymph glands*	Expt. No. 8 Table 2, Sec. b.
109	Feb. 2	Feb. 6	105.6°	None	None	Expt. No. 9 Table 2, Sec. b.
110	April 15	Apr. 18	Below 106.0°	None	None	Expt. No. 10 Table 2, Sec. b.
111	Oct. 21	Oct. 25	105.7°	None	None	Expt. No. 11 Table 2, Sec. b.
112	Jan. 26	Jan. 30	105.2°	None	None	Expt. No. 12 Table 2, Sec. b.
113	Jan. 26	Jan. 31	104.3°	None	None	Expt. No. 13 Table 2, Sec. b.
126	Jan. 22	Jan. 26	104.6°	None	None	Expt. No. 26 Table 3, Sec. b.
127	Jan. 22	Jan. 26	105.2°	Slight dullness	Three or four mesenteric lymph glands	Expt. No. 27 Table 3, Sec. b.
152	Nov. 20	Nov. 24	105.1°	None	Gastro-Hepatic lymph glands*	Expt. No. 53 Table 3, Sec. b.
153	Nov. 20	Nov. 25	105.0°	None	None	Expt. No. 54 Table 3, Sec. b.

1. *—congestion. **—slight hemorrhage. ***—marked hemorrhage.
2. Would not have passed inspection had its temperature been taken ante-mortem.

TABLE NO. 2.

Showing results of feeding fresh pork to susceptible pigs.

Section a. Pork from carcasses that would not pass inspection.

No. of Expt.	Source of infected material	Quantity fed	Pig No.	Date of Feeding	Symptoms Appeared	Date of Death	Remarks
1	Rind and fat from shoulder	4 lbs.	1–2	July 26-30	No symptoms	———	Pigs later proved susceptible.
2	Flesh and bone	3 lbs.	3–4	Oct. 9	Oct. 15	Oct. 20	Pigs killed when very weak. Typical lesions of cholera in both.
3	Flesh and bone	3 lbs.	5–6	Oct. 20	Oct. 28	Nov. 3	Pigs killed when very weak. Typical lesions of cholera in both.
4	Flesh and bone	2 oz.	7–8	Oct. 28	Nov. 8	Nov. 13	Pigs killed when very weak. Typical lesions of cholera in both.
5	Flesh and bone	1 oz.	9–10	Jan. 7	Jan. 12	Jan. 15	Pigs killed when very weak. Typical lesions of cholera in both.

Section b. Pork from carcasses that would pass inspection.

6	Flesh & bone from pig 106 (table 1)	2 oz.	11–12	Feb. 23	Feb. 28	No. 11 Mar. 4	No. 11 showed typical lesions of cholera. No. 12 developed chronic cholera and recovered.
7	Flesh & bone from pig 107 (table 1)	1½ oz.	13–14	Jan. 24	Jan. 29	Jan. 31	Both pigs killed when very weak. Typical cholera lesions in both.
8	Flesh & bone from pig 108 (table 1)	2 oz.	15	Apr. 6	Apr. 11	Apr. 14	Pigs killed when very weak. Typical lesions of cholera in both.
9	Flesh & bone from pig 109 (table 1)	1 oz.	15	Feb. 8	Feb. 13	Feb. 15	Pigs killed when very weak. Typical lesions of cholera in both.
10	Flesh & bone from pig 110 (table 1)	2 oz.	17	Apr. 18	Apr. 22	Apr. 26	Pigs killed when very weak. Typical lesions of cholera in both.
11	Flesh & bone from pig 111 (table 1)	½ oz.	18	Oct. 27	Nov. 2	Nov. 4	Pigs killed when very weak. Typical lesions of cholera in both.
12	Flesh & bone from pig 112 (table 1)	½ oz.	19	Feb. 1	Feb. 7	Feb. 12	Pigs killed when very weak. Typical lesions of cholera in both.
13	Flesh & bone from pig 113 (table 1)	½ oz.	20	Feb. 1	Feb. 7	Feb. 12	Pigs killed when very weak. Typical lesions of cholera in both.

Remarks on table No. 2, Section a. Experiment No. 1 was conducted in very hot weather. The material fed consisted of rind and subjacent fat. Portions were fed during a period of six days, and, especially in the later feedings, a decidedly rancid odor was present. It is possible that decomposition had something to do with the failure of such large quantities to produce infection. The principal point to be noted is that most of the specimens fed produced hog cholera infection.

Remarks on table No. 2, Section b. The experiments recorded in this table were conducted to determine with what regularity fresh specimens from hogs killed while in the early stages of hog cholera, and the carcasses of which would pass inspection, would produce hog cholera when fed to susceptible pigs. Of the eight specimens fed, all produced the disease.

Remarks on table No. 3, Section a. In this table, the meat referred to as frozen was hung in a rather open garret in an unheated building from the time the animals were killed until samples of their flesh were fed. The weather was such that the hams were frozen most of the time but in some cases there were perhaps a few days during which they thawed to some extent. The meat referred to as chilled was placed in an ordinary refrigerator during the time mentioned.

It is very probable that experiment No. 17 would have proved negative had it been possible to obtain a subsequent check on the susceptibility of the pig fed. Litter mates of this animal were susceptible. Under the circumstances though the experiment was classed among those showing undetermined results.

Experiments number twenty and twenty-two show interesting results. In Experiment No. 20 no visible symptoms appeared and no temperatures were taken. The pig subsequently proved to be immune in spite of the fact that it was a litter mate of seven others all of which were highly susceptible. Thus there is very little doubt that the animal was immunized by the material fed to it. Whether the immunizing effect was due to attenuation of the virus or to the small quantity of virus in the specimen is, of course, unknown. In Experiment No. 22 the pig fed showed moderate symptoms but recovered. At one time a temperature of 106°F. was recorded. There is little doubt that it also was immunized in the same manner. Further, it is highly probable that had it been one of a herd of susceptible pigs others would have been infected by associating with it.

TABLE No. 3.

(Showing results of feeding refrigerated pork)

Section a. Pork from carcasses that would not have passed inspection.

No. of Expt.	Source of infected material	Quantity fed	Pig No.	Date of feeding	Symptoms appeared	Death occurred	Remarks
14	Head of femur and flesh. Frozen 20 days	2 oz.	21–22	Feb. 4	No. 21 Feb. 9	No. 21, Feb. 12 No. 22, Feb. 28	No. 21 killed when very weak. No. 22 probably infected from 21. Both showed cholera lesions.
15	Head of femur of ham. frozen 93 days	2 oz.	23	Apr. 6	Apr. 11	Apr. 14	Killed when very weak. Typical cholera lesions.
16	Head of femur and flesh from ham frozen 62 days. No. 395.	2 oz.	24	Mar. 25	Mar. 31	Apr. 5	Typical cholera lesions.
17	Flesh and bone from virus of pig. No. 396. Frozen 62 days.	2 oz.	25	Mar. 25	No symptoms		Pig found April 5 with prolapsed rectum and was killed. Susceptibility not checked.
18	Flesh and bone from virus pig No. 397. Frozen 62 days.	2 oz	26	Mar. 25	No symptoms	No death	Pig later proved susceptible.
19	Flesh and bone from virus pig No. 398. Frozen 62 days.	2 oz.	27	Mar. 25	Apr. 2	Apr. 5	Lesions of cholera.
20	Flesh and bone from virus pig No. 399.	2 oz.	28	Mar. 25	No symptoms		Pig given 3 c.c. of virus but proved to be immune.
21	Flesh and bone from ham No. 423. Chilled 8 days.	½ oz.	29	May 6	May 11	May 15	No lesions of cholera. Blood proved infectious.
22	Flesh and bone from virus pig No 424. Chilled 8 days.	*	30	May 6	May 12	Did not die	Pig developed symptoms but recovered. Later proved immune.

TABLE No. 3—(Continued)

No. of Expt.	Source of infected material	Quantity fed	Pig No.	Date of feeding	Symptoms appeared	Death occurred	Remarks
23	Flesh and bone from virus pig No. 425. Chilled 17 days	½ oz.	31	June 11	June 15	June 18	Pig killed when very weak. Lesions of cholera.
24	Flesh and bone from virus pig No. 430. Chilled 12 days.	½ oz.	32	Aug 3	Aug. 9	Aug. 11	Pig killed when very weak. Typical cholera lesions.
25	Flesh and bone from virus pig No. 431. Chilled 12 days.	½ oz.	33	Aug 3	Aug. 8	Aug. 11	Pig killed when very weak. Typical lesions of cholera.
	Section b. Pork from carcasses that would have passed inspection.						
26	Flesh and bone from pig No. 126 (table 1). Frozen 58 days.	2 oz.	34	Mar. 25	Mar. 31	Apr. 7	Lesions of cholera.
27	Flesh and bone from pig No. 27. (table 1). Frozen 58 days.	1 oz.	35	Mar. 25	Apr. 2	Apr. 7	Lesions of cholera.

*Specimen not weighed. Small button of bone equal in diameter toa nickel but three times as thick.

In Experiment No. 21 the pig fed developed severe symptoms and was killed in order that its blood might be used for virus. A careful autopsy revealed no lesions whatever so 2 c.c. of its blood were injected into a second pig. This pig developed symptoms of hog cholera and showed on autopsy extensive hog cholera lesions so the experiment was classed among those producing positive results. The original pig fed was simply one of those cases, by no means uncommon, in which the disease actually exists but in which its presence cannot be verified by autopsy.

Remarks on table 4. The cured hams from which the specimens were taken were prepared by a process known as sugar curing. They remained in the brine approximately five weeks, and after being removed were smoked from seven to ten days in green hickory smoke. The brine was prepared according to the following formula:

Common Salt	8 pounds
Brown sugar	2 pounds
Saltpetre	2 ounces
Baking soda	½ ounce
Water	4 gallons

Dissolve all the ingredients in the water. Boil slowly for an hour and skim. Allow to cool before using.

This has been selected as a representative formula for sugar curing. There are, of course, many formulae in use for this purpose but it is not likely that there is much difference in them as far as their effects on hog cholera virus is concerned. The only substances the use of which the federal regulations permit in preserving meats are salt, sugar, various vinegars, pure spices, saltpeter and sodium nitrate. Benzoate of soda may also be used but its presence must be declared on the label, and it cannot in accordance with the pure food law exist in finished food products in excess of 3-10%.

In sugar curing, vinegars are not used and benzoate of soda is used little if at all. Thus the only substances that might be used which do not appear in the above formula are sodium nitrate and pure spices. The former ingredient may be used to some extent in sugar curing processes, and of the spices, black pepper is quite frequently used. It is not likely though that sodium nitrate exerts more detrimental effects on virus than the corresponding potassium salt, and in the quantities in which they are used in

TABLE NO. 4.

Showing results of feeding cured pork.

Section a. Pork from carcasses that would not have passed inspection.

No. of Expt.	Source of infected material	Quantity given	Pig fed	Date of feeding	Symptoms appeared	Death occurred	Remarks
28	Subcutem injections of washings from bone. Ham 307.	6 c.c. each	36–37	Feb. 28	Mar 7	No. 36, Mar. 13 No. 27, Mar. 23	Both showed typical cholera lesions.
29	Rind from ham 307	4 oz.	38	Feb. 28	No symptoms	No death	Pigs later proved susceptible.
30	Head of femur and flesh from ham 307	2 oz.	39a–39b	Feb. 28	Mar. 4		39a showed lesions resembling cholera. 39b showed lesions of cholera.
31	Subcutem injections of bone marrow washings from ham 308.	10 c.c.	40	May 18	May 24	39a, Mar. 6 39b, Mar. 10	Animal killed when weak. Typical cholera lesions.
32	Material from ham 308.	2 oz.	40	May 18	May 23	Mar. 28	Animal killed when weak. Typical cholera lesions.
33	Meat and bone from ham 323.			July 15	July 18	No death	Cholera discovered in herd from which pig was taken. Experiment valueless.
34	Rind from ham 323	½ lb.	44	July 15	July 20	No death	Cholera of a subacute type discovered in herd from which pig was taken.
35	Injections from bone marrow washings. Ham 323.	20 c.c.	46–47	July 15	———	———	No symptoms appeared. Animal later proved immune. Cholera discovered in herd from which pig was taken.
36	Injection of bone marrow washings. Ham 324b.	10 c.c.	48–49	Sept. 30	No symptoms	No symptoms	Pigs later proved susceptible.
37	Rind from ham 324	½ lb.	50–51	Sept. 30	No symptoms	No symptoms	Pigs later proved susceptible.
38	Injection from bone marrow washings 323b.	5 c.c.	52–53	Oct. 6	No symptoms	No symptoms	Pigs later proved susceptible.
39	Material from ham 323b.	4 oz	54–55	Oct. 6	No symptoms	No symptoms	Pigs later proved susceptible.

TABLE NO. 4—(CONTINUED).

No. of Expt.	Source of infected material	Quantity given	Pig fed	Date of feedng	Symptoms Appeared	Death occurred	Remarks
40	Rind from ham 323b.	½ lb.	56–57	Oct. 6	No symptoms	No symptoms	Pigs later proved susceptible.
41	Meat and bone from ham 378.	2 oz.	58	Feb. 6	Feb. 11	Feb. 15	Pigs killed when weak. Typical cholera lesions.
42	Meat and bone from ham 378b.	2 oz.	59	Feb. 24	Mar. 1	Mar. 5	Pig killed when very weak. Typical cholera lesions.
43	Meat and bone from ham 379.	2 oz.	60	Feb. 24	Mar. 5	Mar. 5	Pig killed when very weak. Typical cholera lesions.
44	Meat and bone from ham 379b.	2 oz.	61	Feb. 24	Mar. 1	Mar. 5	Pig killed when very weak. Typical cholera lesions.
45	Meat and bone from virus pig 413.	½ oz.	62–63	July 27	———	———	Pigs later proved susceptible.
46	Meat and bone from virus pig 414.	½ oz.	64–65	June 27	———	———	Pigs later proved susceptible.
47	Meat and bone from virus pig 415.	½ oz.	66–67	June 27	———	———	Pigs later proved susceptible.
48	Meat and bone from virus pig 440.	1 oz.	68	Oct. 18	———	———	Pigs later proved susceptible.
49	Meat and bone from virus pig 441.	1 oz	69	Oct. 18	———	———	Pigs later proved susceptible.
50	Meat and bone from virus pig 442.	1 oz.	71	Oct. 18	———	———	Pig later proved susceptible.
51	Meat and bone from virus pig 515.	1 oz.	71	Mar. 16	Mar. 22	Mar. 28	Typical cholera lesions.
			Section b.				
52	Material from pig No. 152, Table No. 1.	½ oz	72	Feb. 16	———	———	Pigs later proved susceptible.
53	Material from pig No. 153, Table No. 1.	½ oz.	73	Feb. 16	Feb. 23	Feb. 28	Pig killed when very weak. Typical cholera lesions.

sugar curing it is doubtful if any of the spices operate to kill hog cholera virus.

The outstanding fact brought out in table number four is that the virus of hog cholera in pork is frequently but not always killed during the process of sugar curing. Just what makes the difference between those cases in which it is killed and those in which it is not killed? The three controllable factors involved in the destruction of viruses by chemicals are the kind of chemical used, its dilution, and the time during which it acts. Can any of these influences be so modified that they will destroy the virus in all cases? This is a question that still remains to be answered.

As circumstances now appear there seem to be no chemicals that could well be substituted for salt and sugar as preservatives. The strength of the brine might be increased but there is a limit to an increase that would still leave the meat palatable. Increasing the time during which pork is in cure or increasing the time during which it is in the store house after being cured may offer possibilities. The fact that the virus was killed in so many of the specimens might seem to indicate that the time limit during which it can survive the sugar curing process was being approached. As a matter of fact, however, there seems to be no definite relation between the time which the hams were in the store room and the certainty with which specimens from them would prove infectious. All the hams were in cure approximately six weeks. The time during which different ones were in the store room varied from two to eighty-four days. Specimens from the hams representing these two extremes did not prove infectious. On the other hand specimens from two hams in the store room fifty-seven and eighty days respectively were found to contain living hog cholera virus. It thus appears that if time is to be employed as a factor in destroying hog cholera virus in sugar cured pork, store room cost and interest on money invested must be considerations.

It will be observed that although rind was fed in large quantities in individual cases, no infection was caused by it. It was fed in only three experiments though, and so few negative results cannot have much significance. In one instance, ham No. 307, feeding the rind did not produce infection and flesh and bone and also bone marrow washings from the same ham produced hog cholera. In this one instance the virus was evidently killed in the rind when it survived in the deeper parts. Since rind is very

likely to find its way into garbage it is a matter of interest and importance to determine how frequently it carries hog cholera virus, and it is to be regretted that during the time these experiments were in progress scarcity of susceptible pigs prevented determinations of this kind. They are not, though, essential. The real problem is not to determine whether there are parts of a ham that do not contain hog cholera virus; it is rather to determine whether there are parts that do contain it. Bone and bits of clinging flesh are frequently placed in garbage and danger is always present in case they contain virus. It is simply present in a greater degree in case it is found that rind also produces infection.

Besides hams, the parts most frequently sugar cured are shoulders and bacon. There are no good reasons to doubt that shoulders carry hog cholera virus in about the same proportion of cases that hams carry it. It seems quite probable that cured bacon, because of its thinness and because of the relative lack of vascularity of its parts, is less likely to contain virus than are hams and shoulders. This is a point that must be determined with certainty before carcasses showing slight lesions only can be disposed of in the most economical manner.

Viewing the entire situation from the standpoint of biology a very interesting group of co-related facts is encountered. If the filterable virus were possessed of human intelligence it could scarcely devise a more insidious and ingenious method of self preservation. It is known to multiply only in the bodies of swine and conditions favorable for its growth are therefore much restricted. Nevertheless, the difficulties met are overcome in a remarkable manner. The virus exists in the blood stream of the animals it infects and is thus distributed to all parts of the body; it cannot at any time be detected with the microscope; it is present in carcasses before gross examinations will detect it; it does not infect human beings and thus escapes radical measures that would otherwise be taken for its destruction; its presence in herds often drives them to market; it secretes itself in pork where putrefaction, its most deadly natural enemy, is prevented or delayed by curing and low temperatures; then as a final link in a remarkable chain, the virus, in placing itself where possibilities for its distribution are practically limitless is at the same time placing itself in material which as a common practice is fed to hogs.

TABLE NO. 5.

Summary.

Kind of pork	Total No. of Expts.	Number positive	Number negative	Number undetermined	Per cent* negative	Per cent positive	Remarks
Fresh carcasses that would have been condemned.	5	4	1	—	80	20	
Fresh carcasses that would have passed inspection.	8	8	—	—	100	—	
Refrigerated carcasses that would have been condemned.	12	8	1	3	88.8	11.2	
Refrigerated carcasses that would have passed inspection.	2	2	—	—	100	—	Small No. of experiments. Percentage not significant.
Cured carcasses that would have been condemned.	24	9	12	3	43	57	
Cured carcasses that would have passed inspection.	2	1	1	—	50	50	Small No. of experiments. Percentage not significant.

*In figuring percentages undetermined results are not considered.

In general, the results shown in table No. 2, Section b, should constantly be thought of in connection with those obtained in tables No. 3, Section a, and 4, Section a. The experiments recorded in table No. 2, Section b, were conducted to determine whether hog cholera virus in sufficient quantities to infect swine is contained in hams taken from hogs killed while in the early stages of the disease. The experiments recorded in tables No. 3, (Section a) and 4, (Section a) were conducted to determine the effects of refrigeration and sugar curing on the life of hog cholera virus contained in hams. It seemed desirable in conducting the latter experiments to use hams from pigs known to be infected; otherwise it would not have been known whether negative results were due to absence of virus in the hams before they were treated, or to the fact that the virus was killed during the processes of refrigeration and sugar curing.

The experiments established two important facts; first, hog cholera virus in sufficient quantities to infect swine is quite constantly contained in fresh hams taken from hogs killed before symptoms, (other than rise in temperature) appear, and before lesions form; second, when specimens were taken from pigs showing lesions, 43% of the cured ones and 88% of the refrigerated ones proved infectious.

Providing all originally contain virus in quantities sufficient to kill, there can, as far as we can see, be no conceivable difference between hams taken from pigs showing lesions and those taken from pigs that do not show lesions, as far as the effects of curing and refrigeration on the virus contained in them is concerned. However, in order to remove doubt concerning this point, experiments were conducted with two cured hams (table No. 4, Section b) and two refrigerated hams (table No. 3, Section b) taken from pigs showing no symptoms other than elevation of temperature and no lesions. One of the cured specimens and both of the refrigerated ones produced infection. It therefore seems likely that had the hams referred to in table No. 2, Section b, been subjected to curing or refrigerating processes, the results would have been similar to those obtained from feeding specimens from virus pigs showing lesions.

When the results of the experiments just described are examined in their relation to practices observed in marketing, slaughtering, and inspecting swine, there are several phases of the situation that deserve consideration.

Relative to marketing we are at once brought face to face with the fact that 40% of the pork consumed and 15% of that which is marketed in the country is not inspected. This is killed on farms, by local butchers, and by packing establishments that do not supply an inter-state trade. It is a well known fact that many herds are marketed as soon as hog cholera infection is discovered in them, and in places where there is no inspection practically all hogs that appear well on foot are killed and sold for food. It is needless to add that large numbers of virus carrying carcasses must be included among those that reach our markets from these sources. Circumstances thus point to a need for extension of both local and federal inspection.

Turning now to the pork inspected under federal regulations let us examine the regulations themselves with a view to determining how they operate to eliminate from the market carcasses that contain hog cholera virus. First, though, it should be stated that the federal regulations compare favorably with those in force in other countries. The efficiency and thoroughness with which they fulfill their lawful purpose—the protection of human health and human life—is not questioned, but if they do not at the same time operate to protect the swine industry of the country, this fact and the reasons for it should be known, the situation should be looked squarely in the face, and a remedy for it should be sought.

Under existing conditions a consignment of cholera infected hogs reaches market and is first subjected to ante-mortem inspection. With respect to hog cholera, it may contain five classes of hogs: first, dead hogs; these are condemned and tanked; second, hogs that show undoubted symptoms of cholera; these are also condemned and tanked; third, hogs that show suspicious symptoms and temperatures below 106°F.; these are slaughtered; carcasses that show lesions of hog cholera are condemned or passed for sterilization according to the extent of the lesions; those that show no lesions are passed for food; fourth, apparently normal hogs (and those showing suspicious symptoms) that have temperatures above 106; these are condemned or isolated for further temperature records; in case further temperatures are taken the animals are condemned if their temperatures are still above 106°; otherwise they fall into class three or class five; fifth, apparently normal hogs that show temperatures below 106°F.; these pass ante-mortem inspection and post-mortem as well if they do not show

lesions of hog cholera in organs other than the kidneys or lymph glands.

Briefly stated, the requirements in order that a given hog may pass inspection are that it shall not show undoubted symptoms of hog cholera, it shall not show suspicious symptoms plus any hog cholera lesions, it shall not show a temperature above 106°F., and regardless of ante-mortem findings the carcass shall not on post-mortem show hog cholera lesions in organs *other than the kidneys or lymph glands.* What are the chances for virus carrying carcasses to pass inspection? A consideration of symptoms, temperatures, and lesions in their relation to the time at which the flesh becomes infectious, will throw some light on this point.

Relative to symptoms, it need only be stated that a hog will usually show elevation of temperature from one to three days before any marked symptoms of hog cholera appear. The excitement to which hogs are subjected in shipping probably lengthens this time to some extent, because under such circumstances, a slight dullness and sometimes even graver symptoms cannot even by the closest scrutiny be detected.

The temperature record, especially when the dividing point is placed as high as 106°F., offers a very uncertain standard upon which to separate infected animals from sound ones, but it constitutes a most valuable adjunct to other factors employed for the purpose. In the first place there is a wide variation in the normal temperatures of swine—from 101°F. to 104°F. In the second place weather conditions, excitement due to shipping, and other factors that cannot be controlled alter otherwise normal temperatures very materially. It is very probable that most of these influences when they affect temperatures noticeably, operate to elevate rather than to lower them, and this probably is the reason why the dividing point—106°F.—has been placed so high. It is certain that some hogs may carry temperatures near 106° as a result of excitement or exertion, and it is equally as certain that many others carry temperatures below 106° when they are suffering with hog cholera.

Another important thing to recognize is the *usual* hog cholera curve. It rises quite rapidly as a rule, remains high for a few days, and then takes a decided drop, which, if death does not ensue, is followed by a second elevation. The following, reproduced from Hutyra and Marek is intended to show a typical hog cholera

curve. It appears originally in the centigrade scale, but it has for the sake of convenience been changed to Fahrenheit.

The temperature curves we record in young pigs usually rise above 106° for a short time, and as a rule they do not fall quite as low between the first and second elevations as did the above curve (Jan. 21). In other ways the curves we record correspond quite

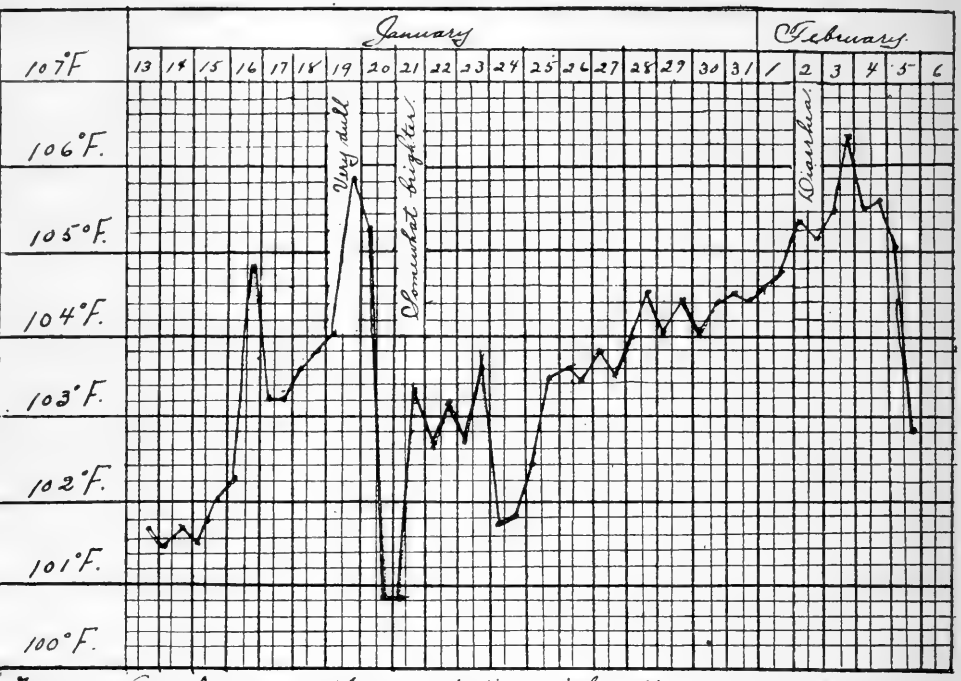


Fig. 1. Hog cholera. Artificial infection with filtered material from a hog affected with cholera. The first rise up to the fourth day of sickness is caused by the primary infection, the second by the secondary infection. (Hutyra and Marek.)

closely to the one shown. In this particular case the animal in question would not, except during the very latest stages of the disease, have been condemned on account of its temperature: symptoms were not recorded until three days after the first decided elevation of temperature occurred; unless the animal was an exception, lesions sufficient to condemn it had not formed during the first day or two on which high temperatures were recorded. Thus there

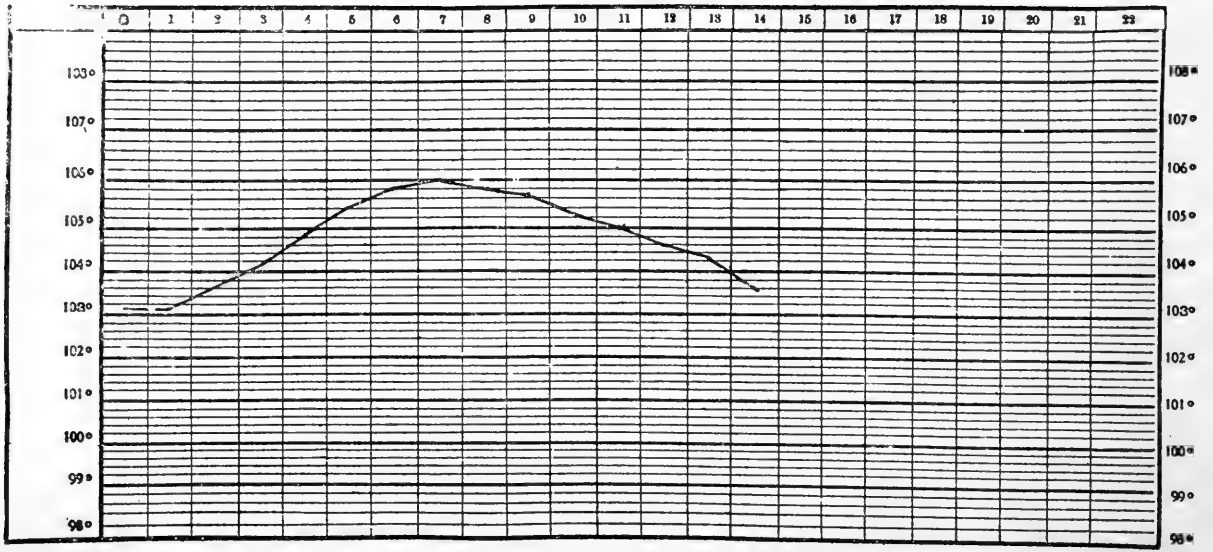
was probably a day or two during which its blood was infectious, when it would have passed inspection.

In order to show more fully something of the number of hogs that will not be rejected on account of high temperatures the following curve, prepared by Craig and Whiting, is reproduced. The animals were infected with intra-muscular injections of small quantities of hog cholera virus. There were 250 of them and the curve shows their average daily temperature during the course of the disease. A second curve, prepared by the same authors, shows the average daily temperature of twenty hogs exposed to cholera by means of natural infection.

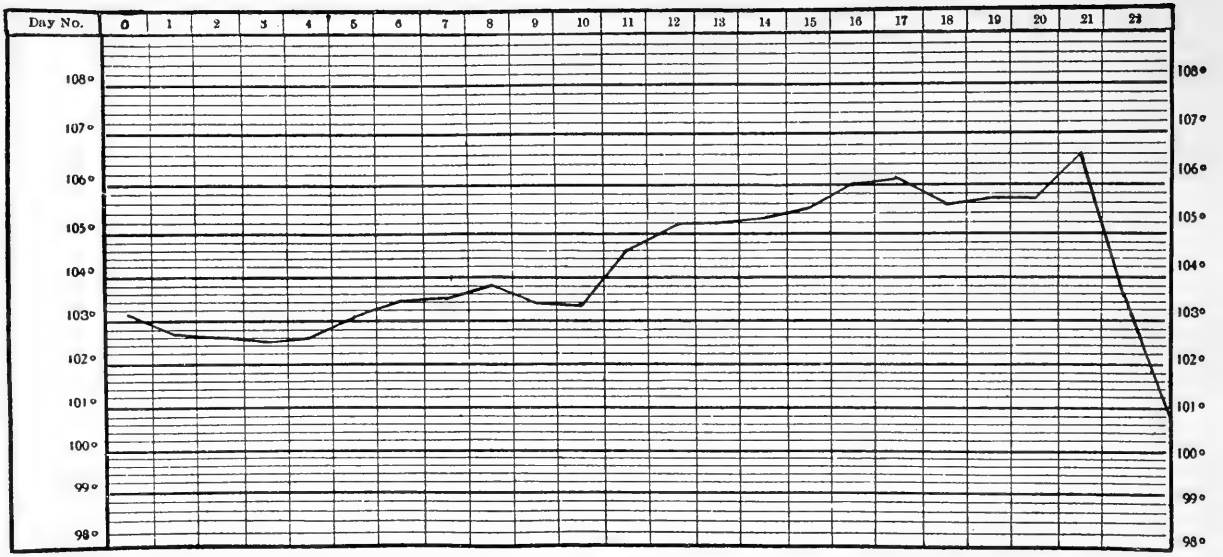
It will be understood that on any given day many of the temperatures were above and many were below the point indicated. It should also be remembered that there was a period during the time when the curve was ascending when a large number of normal temperatures were averaged with a few that were above normal. In this respect the curves are slightly misleading but taken as a whole they indicate that during the course of the disease most of the animals showed temperatures below 106° most of the time.

When the lesions are considered as a factor in determining which carcasses shall be condemned it is to be remembered first of all that in some cases, even when hogs are allowed to die of cholera, lesions do not form at all. Carcasses representing this class together with those that do not show lesions in organs other than the kidneys and lymph glands are allowed to pass. Hogs do not as a rule show marked lesions during the first day or two that elevated temperatures are recorded, and often the time between the first rise in temperature and the time when lesions sufficient to condemn are formed, is of much greater duration. Exemption of the kidneys and lymph glands from consideration unless there are lesions in other organs sufficiently well marked to cause carcasses to be sent to the retaining room, undoubtedly results in passing many virus carrying carcasses.

When table No. 2, is examined in its relation to the symptoms, temperature, and lesions necessary to condemn an animal or carcass for hog cholera, we cannot well escape the conclusion that *there is a time in the life of nearly every hog infected with acute hog cholera when it will pass inspection and when bits of pork from its carcass will prove infectious if fed to other swine.* This time varies from a few hours to several days and is measured,



The above curve was drawn from the temperature records of two hundred fifty pigs and shoats receiving one to two cubic centimeters of hog-cholera blood only. All were killed or died between the seventh and fourteenth days



The above curve shows the average temperature of twenty healthy hogs exposed to hog-cholera in infected pens. All died of the disease

roughly, by the time required for the temperature to rise from normal to 106°, or by the time required for symptoms to develop or extensive lesions to form after the temperature curve starts upward. It is possible that the meat of some hogs is infectious even before the rise in temperature takes place, for it is to be remembered that hog cholera virus *causes* the elevation and it must therefore be present *before* the elevation occurs. Whether, or for how long, it is present in quantities sufficient to infect, and before the elevation of temperature occurs, are questions on which we have insufficient data.

Considering again the infected herd as it is unloaded from the car and comparing it with similar herds in the field in which observations have been made and temperatures have been taken, we cannot help knowing that there are often present in such herds considerable numbers of apparently healthy hogs that show high temperatures due to hog cholera. Some of these are weeded out on account of temperatures above 106°, and a few on account of lesions, but many cannot do otherwise than pass. How many, we do not know, but for purposes of comparison it may be stated that during the decade ending in 1911 a yearly average of 18000 hogs were condemned because of cholera.

Each infected carcass passed possessed almost infinite possibilities in regard to its final distribution. Parts may be worked up into sausage or cooked products and hams, shoulders, and bacon may be cured or shipped in fresh or refrigerated form to supply retail butchers. These facts, coupled with what our experiments have shown relative to the probabilities for the presence of hog cholera virus in market pork, readily lead to the belief that whatever may be the means of spreading hog cholera from herd to herd in different localities, its spread from locality to locality could, if all facts were known, be traced in many cases to shipping and slaughtering hogs in the early stages of cholera and the subsequent sale of pork from the carcasses of these animals.

The results of the experiments described suggest the need of preventive measures for the purpose of diminishing the number of infections due to feeding pork trimmings. These measures naturally fall into three general classes: first, measures to prevent marketing cholera infected hogs; second, measures to turn more carcasses from infected herds into products in which the virus will be killed; third, measures to acquaint swine breeders with the

danger involved in feeding garbage containing pork trimmings, and with the ways to avoid this danger.

Preventing the shipment of cholera infected herds should be the first object sought because it attacks the trouble at its source. There will be widespread infection as long as this is a common practice, and it will be a common practice so long as it is possible to sell infected hogs for the price that sound ones bring. Since the discovery of anti-hog cholera serum the breeder has in it an agent which at any given time will usually protect all of his hogs which are not, at that time, already dangerous carriers of the hog cholera virus. This statement is based on the facts that pork from hogs killed as soon as an elevation of temperature is recorded proves to be quite generally infectious, and that serum will usually protect hogs treated before an elevation of temperature takes place. Thus it is true that the enactment and enforcement of measures to prevent shipping cholera infected herds need not cause undue hardships in any place where hog cholera serum is available.

The economic difficulties involved in condemning or passing for sterilization infected carcasses which, in reality, are entirely fit for human food, are of a nature which render them very difficult to overcome. The scientific difficulties met in seeking to remove all carcasses that contain virus are no less trying. It has been shown that the carcasses of hogs that show no symptoms other than slight elevation of temperature, and no lesions whatever, may contain hog cholera virus sufficient to infect other hogs. Because the normal temperatures of swine vary so widely no mark can be set that will separate out infected animals with any degree of accuracy. A temperature of 104°, for instance, may be normal or three degrees above normal. There is no method known of detecting all virus carrying carcasses, but, as a general principle, we believe that rigid ante-mortem *herd* inspection with a more severe interpretation of temperatures and lesions in hogs that are members of infected herds, together with a tagging system rendering it possible to place losses due to condemnation with the man who ships the hogs, are worthy of consideration. Obviously measures of this kind would serve the double purpose of removing more infected carcasses from sale in the form of raw products, and of preventing the shipment of many infected herds that otherwise reach our markets.

Under existing conditions the most promising outlook for

dealing with this phase of hog cholera control consists in acquainting swine breeders with the dangers incident to feeding their own kitchen refuse, in case there are trimmings from market pork contained in it. The ordinary farmer has recourse to four very effective methods of protecting his herd from dangers incident to garbage feeding; he may keep pork trimmings out of the garbage, he may discontinue the practice of feeding garbage, he may cook all garbage before it is fed, or he may immunize his hogs. Men who collect and feed kitchen refuse from cities have recourse only to the two last named methods of protection.

It is sometimes suggested that statutory restrictions should be placed on feeding collected garbage to hogs. The objections to this practice are that it is in a degree repulsive, and that the heavy losses caused by it more than offset the gain it produces. The first objection is well sustained in many individual cases and in others it is not. The French have a saying, "Not what, but how", and this applies well to the point in question. If the material is fed fairly fresh and if the hogs to which it is fed are provided with clean quarters there are no very well sustained objections to the practice, for the material fed is in the last analysis only the refuse from what we ourselves eat. Many thousand hogs are fattened on garbage each year and statutory restrictions placed on the practice as a whole would not, especially since the discovery of anti-hog cholera serum, be justified.

Cooking kitchen refuse to destroy hog cholera virus contained in it is very effective in individual cases, and it possesses the additional advantage of rendering much of the material in it,—for instance potato parings,—more palatable and more nutritious. It could not, though, be well enforced as a sanitary measure; it is quite expensive in some localities, and, in order to be effective it requires more time and care than most men will give to it.

Serum-virus immunization seems to be the most logical means of preventing hog cholera in large herds that are fed collected garbage. It is effective, reasonably cheap, and has the decided advantage of protecting from infection by channels other than the one incident to feeding kitchen refuse.

Summary and Conclusions

1. Meat and bone taken from the carcasses of hogs killed before any manifestations of hog cholera other than elevation of tem-

perature take place, and at a time when they will pass inspection, will usually produce hog cholera when fed in small quantities to susceptible pigs.

2. In places where meat inspection is maintained, it is impossible, even with the severest interpretation of temperatures, symptoms and lesions now practicable, to remove from market all carcasses of hogs that contain hog cholera virus.

3. We believe a more severe interpretation of temperatures and lesions in hogs known to come from infected herds, will remove many more virus containing carcasses than are now removed, and without resulting in the condemnation of appreciable numbers of carcasses that do not contain virus.

4. The economic difficulties in the way of placing more severe interpretations on temperatures and lesions observed in hogs that are members of infected herds are worthy of study. Whether the number of virus carrying carcasses that pass inspection is large or small, the danger of new infections due to passing them is proportionate to the number passed.

5. In hog cholera infected carcasses that pass inspection:

The virus is not often killed in parts sold as fresh or refrigerated products.

The virus is often, but not always, killed in hams that are sugar cured. (In our experiments in twelve cases in twenty-one).

6. Anti-hog cholera serum will, at any given time, usually save all hogs in a herd the carcasses of which will not at that time, already prove infectious if small parts are fed to susceptible pigs.

7. Measures to prevent hog cholera infections due to feeding trimmings from market pork should include efforts to prevent marketing infected herds, efforts to prevent the sale of carcasses in products in which the virus is not killed, and efforts to acquaint swine breeders with the danger incident to feeding kitchen refuse.

8. Farmers can avoid the danger mentioned by discontinuing the feeding of kitchen refuse, by placing all pork trimmings elsewhere than in the garbage pail, by thoroughly cooking all garbage before it is fed, or by immunizing their hogs. Men who collect and feed city garbage can avoid the danger by cooking all the material they feed, or by immunizing their hogs.

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